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Since the inception of armed conflict, knowledge of the battlespace environment (i.e., terrain and weather) has always been a critical factor in determining the outcome of combat operations. With today's modern weaponry, represented by laser-guided bombs, nap of the earth aircraft, and high-speed armor, knowledge of the battlespace environment is more critical than ever to combat success. Every new weapon, command and control, and intelligence system has a requirement for terrain information. The rapidity and lethality of today's combat operations require commanders at each echelon to know where they are, where their troops are located, and the most likely positioned of enemy forces—all on a common three-dimensional reference system. Planning and maneuver operations require a three-dimensional perception of the battlefield, i.e., the associated terrain and natural (e.g., vegetation) or manmade (e.g., road networks) features and targets. Achieving this perception necessitates the creation of a data base that depicts these features and allows them to be manipulated, combined, and analyzed. Also, battle or naturally induced changes, such as a blown or flooded bridge, need to be incorporated into the geospatial data base and their impact on operations determined (e.g., route re-planning).

DTIC QUALITY INSPECTED

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20. LIMITATION OF ABSTRACT

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GEOSPATIAL DATA - CRITICAL TO COMBAT OPERATIONS

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Since the inception of armed conflict, knowledge of the battlespace environment (i.e., terrain and weather) has always been a critical factor in determining the outcome of combat operations. History is replete with stories of how successful warriors used this knowledge for selecting optimum locations for attack, placing artillery for maximum coverage and identifying choke points and likely avenues of approach/escape. The more detailed and timely the terrain and weather information was, the more effectively it could be exploited. And, when intelligence information of enemy location and size could be overlayed on the terrain, the force multiplication effect was exponential.

With today's modern weaponry, represented by laser-guided bombs, nap of the earth aircraft, and high-speed armor; knowledge of the battlespace environment is more critical than ever to combat success. Every new weapon, command and control, and intelligence system has a requirement for terrain information. The rapidity and lethality of today's combat operations require commanders at each echelon to know where they are, where their troops are located, and the most likely positions of enemy forces--all on a common three-dimensional reference system. Planning and maneuver operations require a three-dimensional perception of the battlefield, i.e., the associated terrain and natural (e.g., vegetation) or manmade (e.g., road networks) features and targets. Achieving this perception necessitates the creation of a data base that depicts these features and allows them to be manipulated, combined, and analyzed. Also, battle or naturally induced changes, such as a blown or flooded bridge, need to be incorporated into the geospatial data base and their impact on operations determined (e.g., route re-planning).

Traditionally, the geospatial reference used by combat commanders has been the standard, hard-copy Topographic Line Map (TLM). Drawn to cartographic specifications--based on scale, projection, required information, and the draftsman's ability to accurately place a point or line on a piece of paper--the TLM contains a host of relevant and sometimes irrelevant information. Each country has developed different standards and presents different amounts of data on their maps. And, in many countries, maps are considered such a vital source of information that they are classified or controlled by copyright. The TLM is an analog version of a geospatial data base. Every piece of information depicted on the map has a two-dimensional, horizontal coordinate and a name or symbol. The elevation, or Z value, is normally interpolated from contours by the user. The production of TLM's is a slow, labor-intensive process requiring considerable cartographic and geodetic expertise. As a result, TLM's are usually out of date.

DTIC QUALITY INSPECTED 3

The Defense Mapping Agency (DMA) is charged with overall responsibility for providing Mapping, Charting and Geodesy (MC&G) data to the U.S. Armed Forces. It responds to area coverage requirements established by U.S. Joint and Unified Commands around the world, prioritized by guidance provided through the Joint Chiefs of Staff (JCS) and the Assistant Secretary of Defense for Command, Control, Communications and Intelligence (ASD-C³I). MC&G product types and scales are defined by each service staff element and coordinated through DMA Headquarters into a set of "standard" products. Needless to say, the overall service MC&G requirements worldwide far outstrip DMA's production capability. DMA does a fantastic job in attempting to meet high- priority requirements and is very proactive in trying to anticipate mapping requirements as new military crises and international emergencies arise. The bottom line, however, is that DMA does not have the resources to satisfy the overall need.

At this point, I will focus on the Army's requirements for MC&G geospatial data and the status of that data. As opposed to the Air Force and Navy, which generally have medium and small scale (1:250,000 and smaller) MC&G requirements to support "strategic" type weapons (e.g., ICBMs, Bombers and Cruise Missiles), the Army's and the Marine Corps' tactical primary mapping needs fall in the 1:50,000 and larger scale range. Until recently, much of the nation's high-priority MC&G requirements centered around Cold War considerations. Thus, the northern hemisphere is reasonably well mapped at the 1:250,000 and smaller scales; although even these products are rapidly aging (see Figure 1). On the other hand, most of the world (except for specific regions in Europe and Korea) is not very well covered with 1:50,000 scale products. (See Figure 2.) This lack of large-scale coverage was emphatically evident during Operations Desert Shield, Provide Hope, Provide Comfort, and now in Rwanda.

I need now to refer back to today's new warfighting hardware and the need to support these military systems with geospatial (read map) data. These systems all require these data in digital, not analog, format. DMA has recognized this requirement and invested very heavily in transforming their production plants to an all digital operation. However, that transformation is not yet complete. To provide a partial solution, DMA has produced digital equivalents of TLM's, called the ARC Digitized Raster Graphic (ADRG), which is essentially a rasterized TLM that can be displayed on a CRT. This digital product is also geographically limited to areas mostly in the northern hemisphere (See Figure 3). The ADRG is often referred to as a "dumb map" in that, although digital, the feature data cannot be manipulated and it cannot be used directly to provide a 3-D visualization of the terrain. DMA also has validated an Army requirement for Tactical Terrain Data (TTD), which provides vectorized digital map overlays (i.e., vegetation, lines of communication, hydrology, soils, and obstacles), and plans initial production of this product in 1996. Lastly, the Army has been successfully exploiting another DMA digital product, called Digital Terrain Elevation Data (DTED), to support its contingency needs. However, this elevation data base, which was produced to

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support strategic weapon requirements, is at a medium-scale equivalent density (1:250,000); not at the 1:50,000 scale density the Army requires (See Figure 4).

Given recent experiences, it is likely that the Army can be called upon to fight (or carry out peace keeping operations) anywhere in the world on very short notice; particularly in third world areas. It can also be asserted that map data (analog or digital) in these areas (should it exist at all) would be of medium or small scale, out-of-date, and of questionable accuracy. To overcome this deficiency, the Army has undertaken several development efforts to provide tactical commanders with quick response, large-scale map substitutes and terrain visualization. The goal is to rapidly establish an initial geospatial data base (or extend an existing data base) to support planning and maneuver operations, until the time when DMA production assets can be directed to support the operation with standard products.

The objective of this program is to quickly produce, at the theater level, an accurate, large-scale ortho-rectified digital image map with a grid overlay that can be generated in hours and field reproduced in hard copy. This digital raster formatted map also needs to be transmitted to deployed units for display and targeting. The basis for achieving this capability is a digital photogrammetric device called TIES, for Terrain Information Extraction System. TIES can automatically correlate stereo-imagery to produce a dense array of elevation points oriented to a prescribed datum. Using the elevation information and knowledge of the orientation of the imagery, each picture element (pixel) is then transformed to remove geometric and relief distortion; thus producing an ortho-photograph. The TIES can accept imagery from a multitude of sensors (frame, panoramic, scanners, etc.) and has demonstrated its utility on several projects.

Having full knowledge of the geometry of the imagery and the surface configuration, the TIES can produce a three-dimensional image perspective transformation (IPT) for any number of points in space; thereby providing a fly-through capability. As more time is allowed, the TIES operator can manually generate terrain feature files from the stereo model using a Geographic Information System (GIS) and a "floating digital dot." The GIS allows merging these data files with DMA-produced digital data (if it exists) and the overlay of intelligence information (ICONS). Figure 5 shows a photograph of the TIES. The beauty of the TIES is its flexibility in handling different types of sensor imagery and the ability to generate digital terrain information to any scale. The input imagery can be either hard copy or digital. In the case of the former, a TIES component can precisely scan and digitize the imagery down to 7 1/2 micrometers in resolution.

Army field commanders have stated formal requirements for a field capability to rapidly produce image map substitutes and 3-D visualization. In response, the Army Staff has funded the development of two prototype systems called TIIP (Topographic Imagery Integration Prototype). TIIP constitutes a total system for receiving and processing a wide variety of image data, generating map-substitute and terrain visualization products, and providing hard copy and digital outputs. The heart of TIIP is the two TIES components discussed previously.

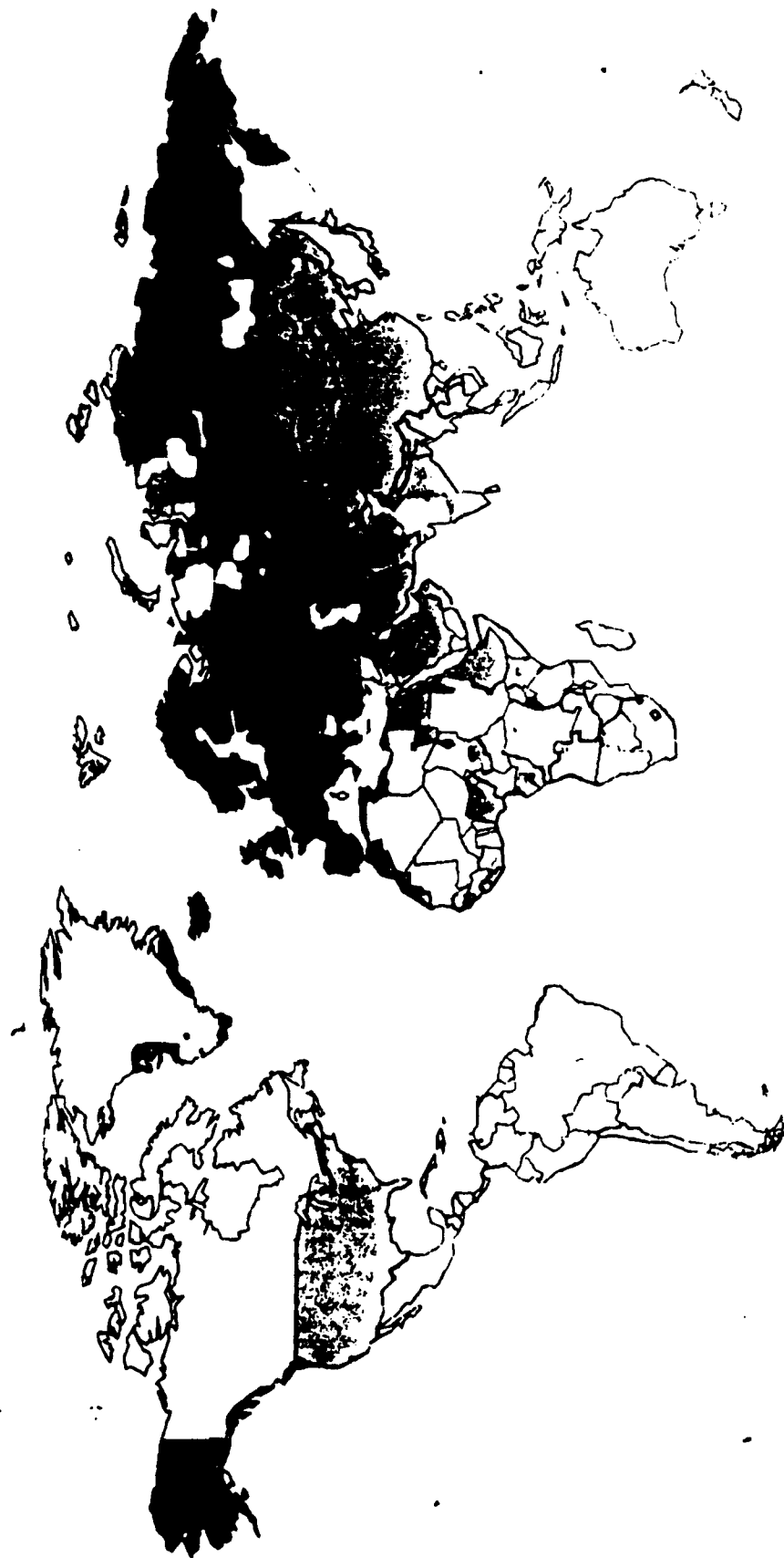
Additional components are computer processors and file servers that contain software to process commercial imagery (ERDAS) and establish a geospatial data base (ARCINFO). Hard-copy outputs are generated by another developmental item called the Quick Response Multicolor Printer (QRMP) for rapid production (10 minutes) of limited copies and a LINOTRONIC printer for press plate ready copies for lithographic, high-rate reproduction. A wiring diagram of the TIIP is shown in Figure 6.

The two TIIP systems are currently being built, with scheduled delivery to the XVIII Airborne Corps and Pacific Command starting in April 1995. In addition, a CONUS-based rapid mapping TIES/TIIP equivalent capability will be maintained at the Army Topographic Engineering Center to provide backup, "split-based" support for contingencies and emergencies. Once instituted, these systems will provide the Army with the capability to generate quick reaction, substitute map products and, as important, an ability for the field commander to visualize the battlefield. He will be able to walk or fly through the terrain, overlay important time sensitive intelligence and make critical decisions on how to fight the next battle.

Longer term R&D activities also are underway, oriented at developing automated methods for extracting terrain information. The goal is to extract natural and manmade features from remotely sensed data sources in three-dimensional space coordinates in near-real-time, such that data required to generate tactical decision aids can be produced in a timely manner. Then, computer programs to process this geospatial data will indeed give the warfighters a major leg up in their ability to visualize the battlefield (See Figure 7); to conduct realistic battlespace fly throughs to play "what if" exercises, and perform mission rehearsals that can significantly improve combat effectiveness and minimize casualty rates.

JOINT OPERATIONS GRAPHICS

1:250,000 SCALE

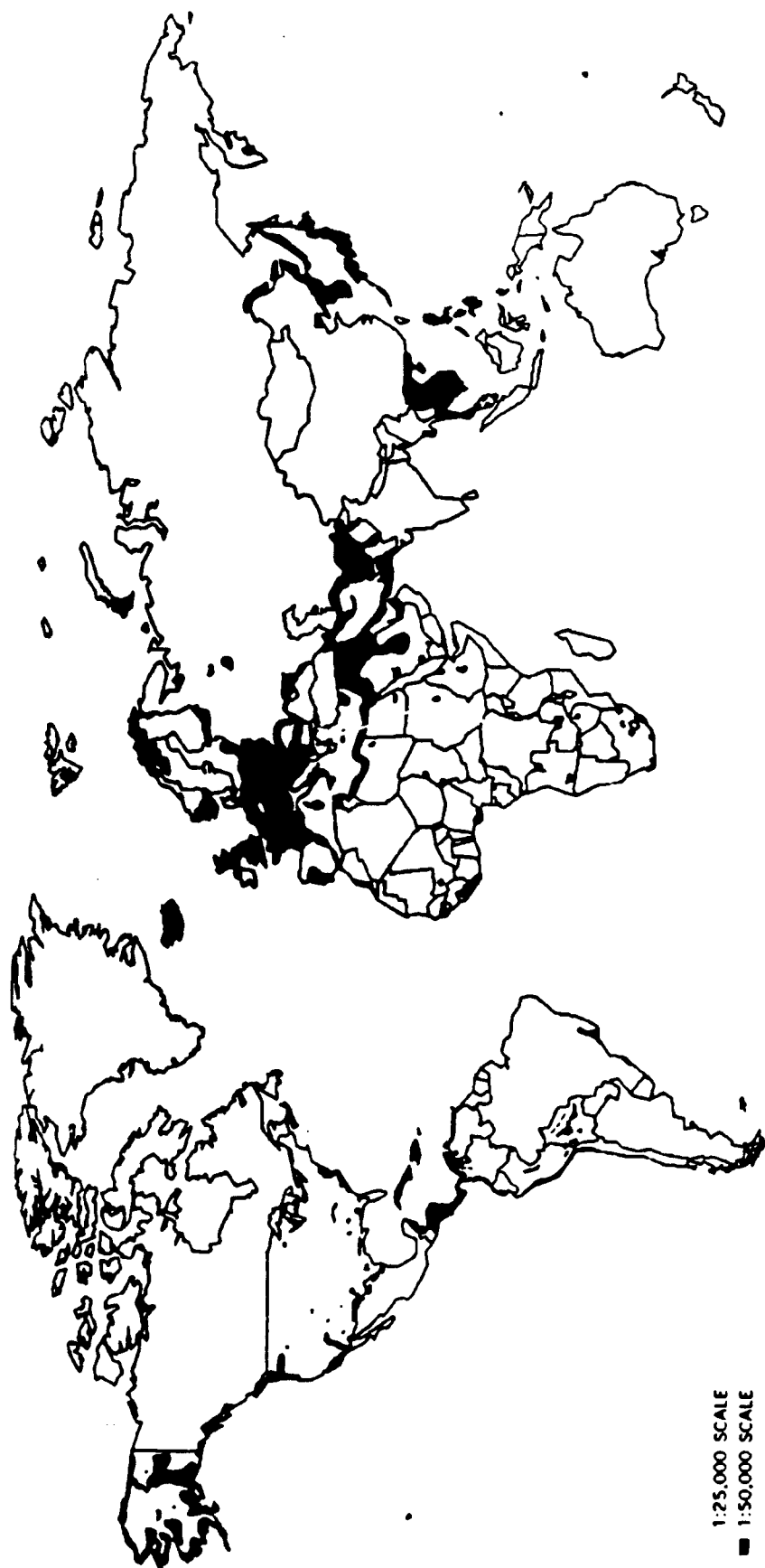


NOTE: Coverage shown is based on Defense Mapping Agency Catalog of Maps, Charts, and Related Products Part 1 Volume 1 Aerospace Products (January 1992) Part 3 Volume 1 Topographic Products (April 1993) and the best information available at time of revision.

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Figure 1

TOPOGRAPHIC LINE MAPS (TLMs)



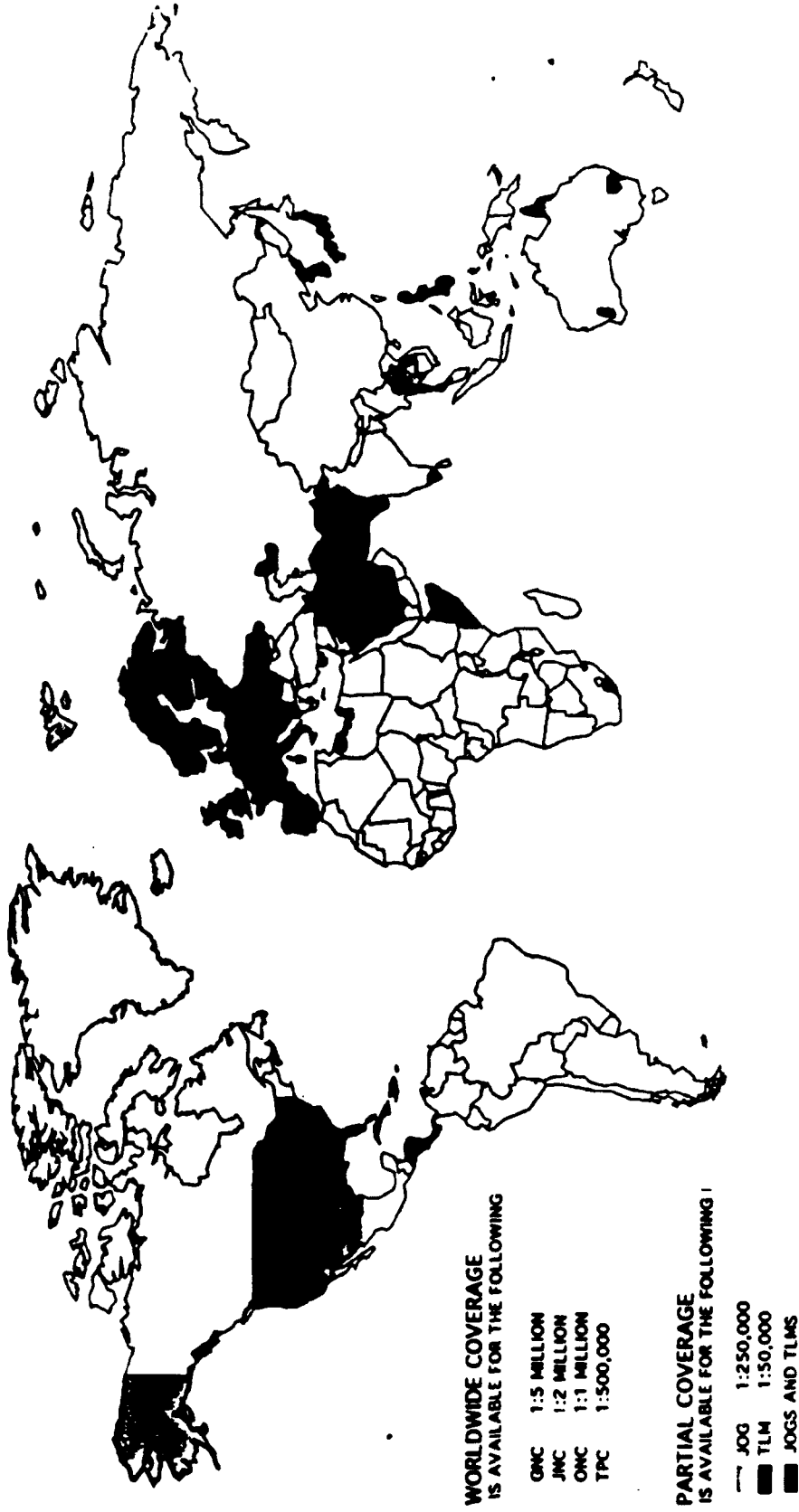
- 1:25,000 SCALE
- 1:50,000 SCALE
- 1:63,360 SCALE
- 1:100,000 SCALE

NOTE: TLM coverage over Germany is available at both 1:50,000 scale and 1:100,000 scale.
 From Defense Mapping Agency Catalog of Maps, Charts, and Related Products
 Part 3 - Volume 1 Topographic Products (April 1993) and the best information
 available at time of revision.

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Figure 2

ARC DIGITIZED RASTER GRAPHICS (ADRG)

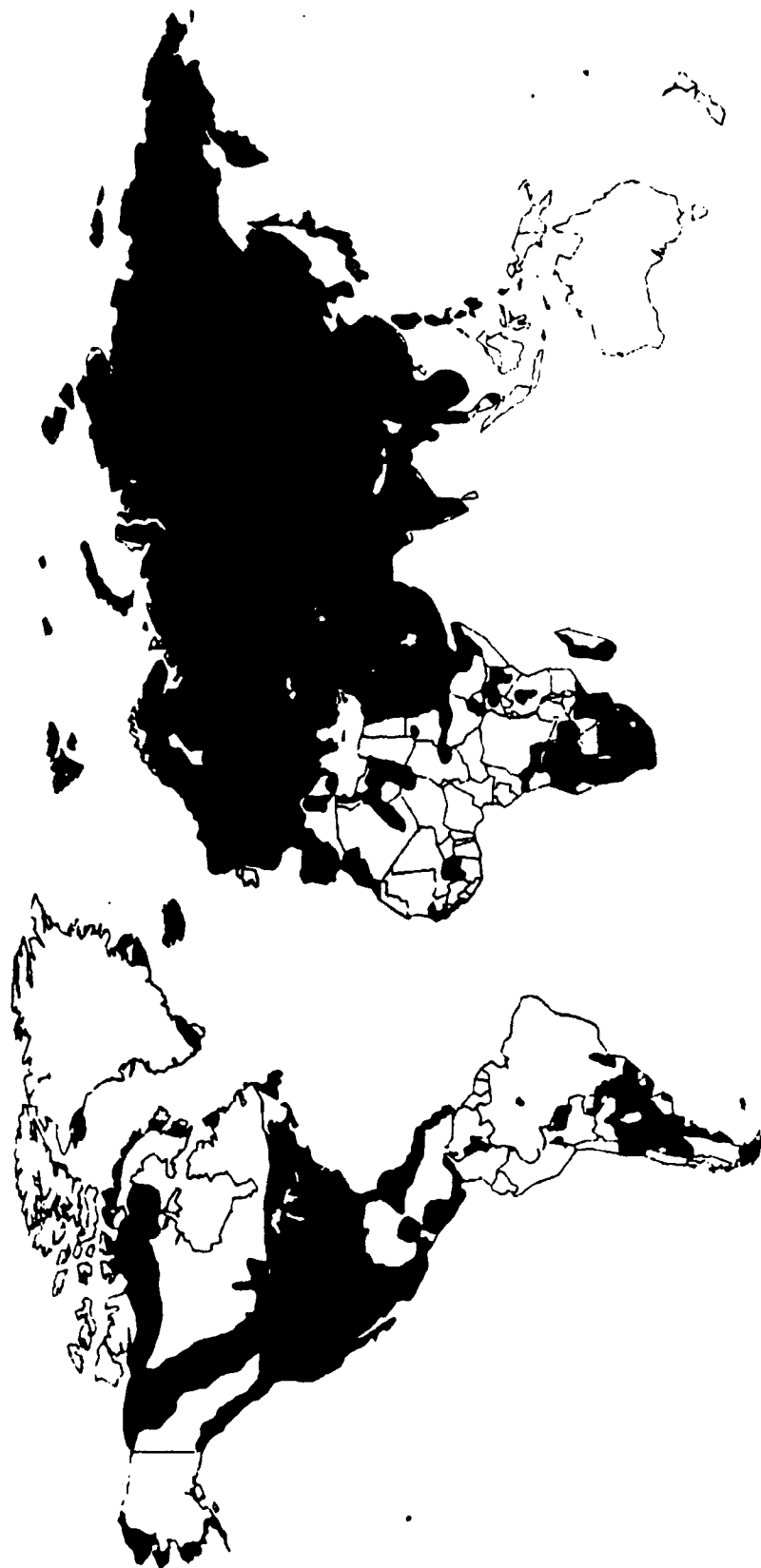


NOTE: Coverage shown is based on Defense Mapping Agency Catalog of Maps, Charts, and Related Products Part 7 - Volume III Digital Data Products ARC Digital Raster Graphics (ADRG) and the best information available at time of revision.

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Figure 3

DIGITAL TERRAIN ELEVATION DATA (DTED)



NOTE: Coverage shown is based on Defense Mapping Agency Catalog of Maps, Charts, and Related Products, Part 7, Volume I, Digital Data Products Terrain, Feature, and World Vector Shoreline Data (October 1992) and best information available at time of revision.

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Figure 4



Figure 5

TIIP FUNCTIONAL FLOW

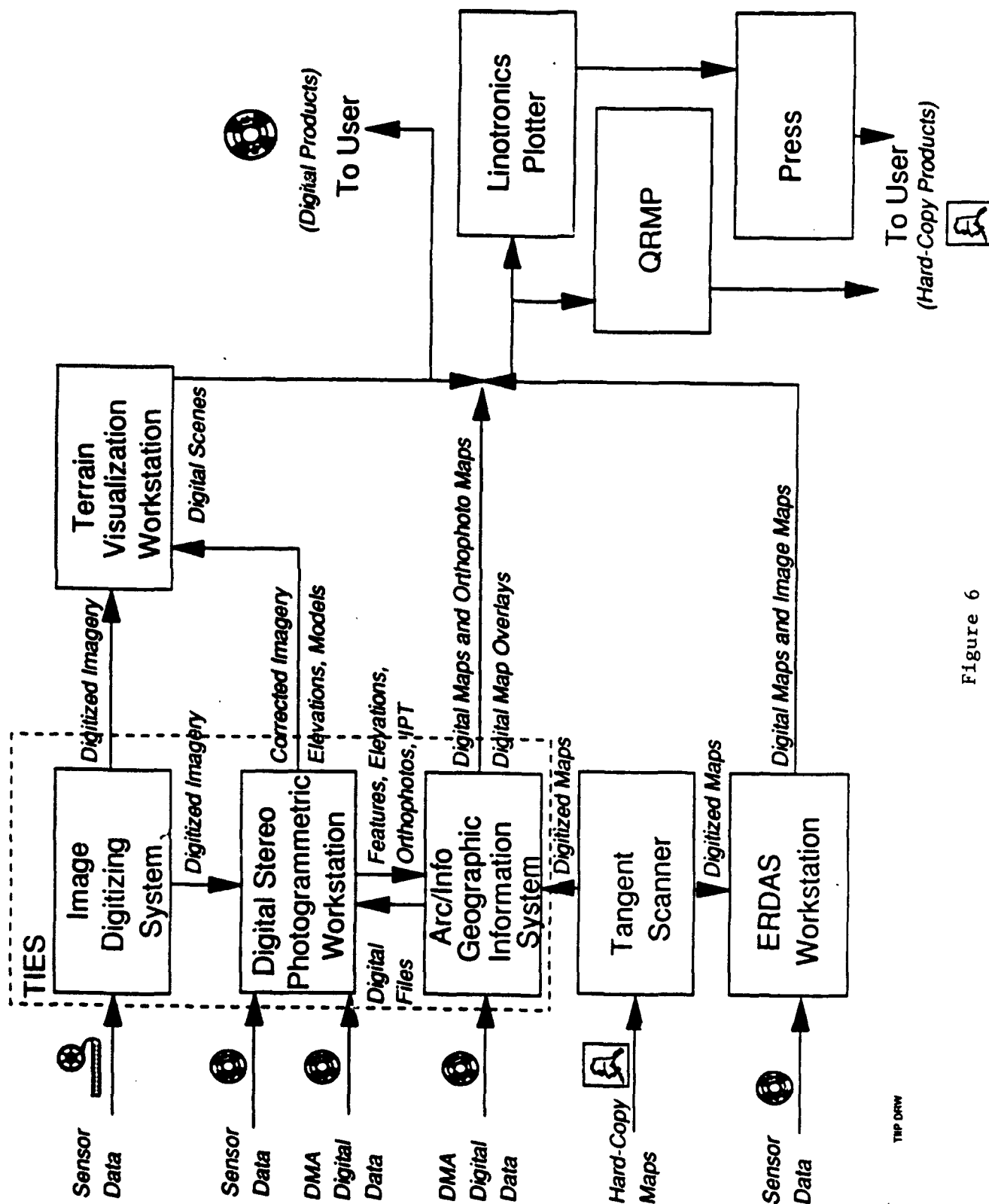


Figure 6

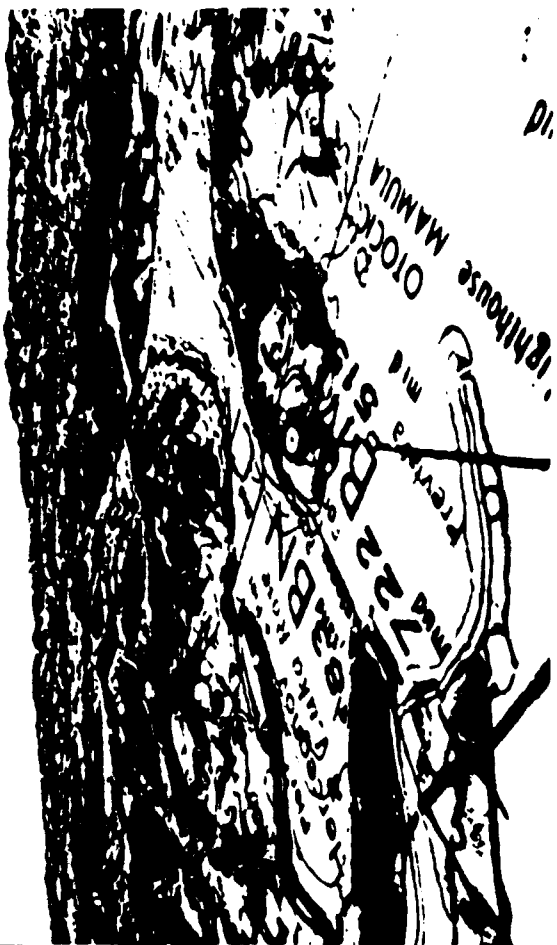


Figure 7